RECLAMATION

Managing Water in the West

Basin Study Framework: *WaterSMART Program*

U.S. Department of the Interior
Bureau of Reclamation

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Mission Statements

The mission of the Department of the Interior is to protect and provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to Indian Tribes and our commitments to island communities.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

BUREAU OF RECLAMATION

Basin Study Framework:
WaterSMART Program

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1.0 Synopsis of the Basin Study Program

The Basin Study Program is part of the Department of the Interior's WaterSMART Program, which addresses 21st century water supply challenges such as population growth, increased competition for finite water supplies, and climate change. Moreover, as a key component of Reclamation's plan for implementing the Secure Water Act, Subtitle F of P.L. 111-11, the studies will specifically consider the risks to water supplies enumerated in § 9503(b)(2) of the SWA, and the water resources impacts identified in § 9503(b)(3), to the extent applicable.

Through the Basin Study Program, Reclamation will partner with basin stakeholders to conduct comprehensive studies to define options for meeting future water demands in river basins in the West where imbalances in supply and demand exist or are projected. Reclamation will collaborate with willing states and local entities on a 50/50 cost-share basis to conduct the studies. Because this is not a financial assistance program, Reclamation's share of the study costs may only be used to support work done by Reclamation or its contractors. Reclamation may not pass funding directly through to the non-Federal cost-share partners in the form of grants or cooperative agreements.

Basin Studies will identify basin-wide water supply issues that could potentially be resolved with changes to the operation of water supply systems, modifications to existing facilities, development of new facilities, or non-structural changes. The studies will incorporate the latest science, engineering technology, climate models and innovation. The desired outcomes are basin-specific plans recommending collaboratively developed solutions that will help meet water demands and foster sustainable development, and leading to congressionally authorized feasibility studies.

The 50/50 cost-share requires basin stakeholders and Reclamation to build capacity and collaboration in the process of identifying adaptation options for water management given identified water supply imbalances. Through these studies, we can gain a common understanding of potential risks and impacts to water management from climate change and other stressors, set joint goals to identify adaptation options, and conduct trade-off analyses to identify potential solutions.

2.0 WaterSMART Program

Water issues and challenges are increasing across the Nation but particularly in the West and Southeast due to prolonged drought, exacerbating the challenges facing traditional water management approaches. The Department's WaterSMART (Sustain and Manage America's Resources for Tomorrow) Program is working to achieve a sustainable water strategy to meet the Nation's water needs now and for the future.

The WaterSMART Program includes three Reclamation programs:

1. *Basin Study Program.* In addition to the comprehensive basin-wide water supply and demand studies described in this framework, West-Wide Risk Assessments (WWRA) and Landscape Conservation Cooperatives (LCC) will provide tools for analyzing and addressing climate change impacts.

   The WWRA will complement the Basin Studies by providing key data on climate induced risks and impacts to Reclamation's operations (including climate projections, baseline water supply, water demand, operational, and environmental response analyses) that will provide a foundation for future Basin Studies as well as project specific applications. The WWRA will allow Reclamation to apply a consistent approach throughout the West in order to assess the impacts of climate change on water supplies. This will supply Reclamation with a baseline for more in-depth analyses, and may support adaptation options explored through future Basin Studies.

   LCCs are partnerships between Federal Government agencies and States, Tribes, Non-Governmental Organizations and other stakeholders that bring together science and resource conservation. This partnership will inform adaptation strategies addressing climate change and other stressors within an ecological region, or "landscape." In 2010, Reclamation has begun work to develop two new LCCs that include Colorado River Basin and Rio Grande. After evaluating the science and technical capabilities needed to support two LCCs in this geographic area, Reclamation will fully establish the LCCs in 2011.

2. *WaterSMART Grants.* Reclamation will undertake a competitive process to award WaterSMART Grants (formerly known as Challenge Grants) for projects that save the most water, facilitate transfers to new uses, address endangered species issues, improve energy efficiency, and conserve Reclamation project water.

3. *Title XVI Program.* Through this program, Reclamation will continue to provide cost-shared funding to plan, design, and construct water recycling projects.

For its part of WaterSMART, the USGS will undertake a census of water availability and enhance the nation's stream gauging network. The census includes larger-scale regional studies and smaller, focused area studies. The regional studies will develop water budgets and analyze hydrologic trends in each of the 21 major river basins in the Nation over the next 10 years. The USGS focused area studies will include an in-depth analysis of hydrologic processes such as ecological flows, aquatic habitat requirements, and ground and surface water interactions in smaller study areas. The USGS water census activities will provide valuable data that will be incorporated into Reclamation's Basin Studies wherever possible.

To learn more about WaterSMART, please visit our website at: http://www.usbr.gov/WaterSMART/.

3.0 The Basin Study Framework

The purpose of this Basin Study Framework is to provide guidance to participants in the Basin Study Program on the process for conducting a Basin Study. A detailed description of the process for submitting a proposal to conduct a Basin Study is provided separately, in the accompanying *Basin Study Program – Selection Process Overview* document.

This Framework describes three items:

- The Basin Study Program including programmatic criteria and requirements;
- The requirements for conducting a Basin Study; and
- The suggested content of a Basin Study.

Because each Basin Study will focus on a different basin or sub-basin, each study will involve water supply issues and study needs that are unique to that basin. As a result, no two Basin Studies will be exactly the same. With this in mind, the Framework provides the requirements, suggested content and approach for conducting the studies, while allowing Reclamation and the non-Federal cost-share partners (Reclamation and the non-Federal cost-share partners are referred to collectively as the Cost-Share Partners) to develop specific requirements for each study individually. The individual study requirements will be set forth in an agreement (the Memorandum of Agreement [MOA]), entered into between the Cost-Share Partners. The terms of the MOA will be consistent with this Framework, but will provide the flexibility to address issues particular to the basin being studied.

4.0 The Basin Study Program

4.1 Overview

Reclamation will work in partnership with state and local entities to perform Basin Studies in the West. The availability of funding and implementation of the studies are contingent upon congressional approval of annual funding requests. The studies will be cost-shared with willing state and local partners and will generally be two years in duration.

We estimate that approximately $500,000 to $1.5 million in Federal funding will be required for each Basin Study, in addition to non-Federal cost-share contributions of at least 50 percent. However, the actual amount of funding required for each study will vary depending on the size and complexity of the basin selected, the issues involved, and the availability of applicable data and models. Future year appropriations may be used to complete ongoing Basin Studies first and the remaining funding applied towards the initiation of additional Basin Studies.

4.2 Proposal Selection Process

As described in more detail in the *Basin Study Program – Overview of Proposal and Selection Process*, the initial screening of proposed Basin Studies will be done within Reclamation's five regions. The regions will initiate the selection process by contacting stakeholders in their areas to determine if there is interest in cost-sharing a basin-wide study in partnership with Reclamation. Reclamation's regions will identify proposed studies that merit further review, and will work with the non-Federal study proponents to develop a proposal for submittal to a Reclamation Application Review Committee (ARC). The Reclamation ARC will be made up of Reclamation staff from the regions and area offices, and other technical experts as needed. The ARC will evaluate and rank the proposed studies using the selection criteria listed below, and will recommend the selected studies to Reclamation's Commissioner for approval. The selection criteria include:

- The extent and consequences of existing or anticipated water supply imbalances (30 Points)

- The extent to which Federal involvement is needed due to the nature and complexity of the issues involved (20 Points);

- The existence and quality of data and models available and applicable to the study (15 Points);

- The strength of any nexus between the Basin Study and a Reclamation project or activity. Studies with a stronger nexus will receive a higher score. (15 Points);

- The level of stakeholder interest in and support for the Basin Study (10 Points);

- Whether the study will complement, or adversely complicate ongoing efforts in the study area (7 Points); and

- Whether the non-Federal cost-share contribution exceeds the required 50 percent. Non-Federal cost-share contributions of greater than 50 percent will result in a higher score (3 Points)

4.3 Administration of the Basin Study Program within Reclamation

Implementation of the Basin Studies will be managed locally by Reclamation's regional and area offices. Budgeting and policy for the program will be managed centrally by the Office of Policy and Administration (Policy), a branch of Reclamation's Commissioner's Office located in Denver, Colorado. Policy staff will oversee the study selection process. Once a proposed study has been selected for funding, the region and area offices will be responsible for all aspects of conducting the studies and for involving the non-Federal partners and stakeholders in that process. Centralized policy and budgeting will provide for consistent administration of the program across the regions, and decentralized implementation will allow for hands-on involvement by Reclamation staff with technical expertise and familiarity with local stakeholder concerns and interests.

4.4 Program Requirements

4.4.1 Eligible Cost-Share Partners

Non-Federal entities that are eligible to cost-share with Reclamation to conduct a Basin Study include those with water delivery or water management authority within the basin, including: State(s), cities, or sub-divisions of a state or city; Tribes or tribal water organizations; irrigation or water districts, water conservancy districts and other similar associations. Together, the Cost-Share Partners will seek input from other non-Federal and Federal basin stakeholders who do not qualify as cost-share partners during the study process.

4.4.2 Cost-Share Requirements

Consistent with Reclamation's other planning programs; a non-Federal cost-share contribution of at least 50 percent of the total study costs is required to be contributed by the non-Federal Cost-Share Partners under the Basin Study

Program. In exceptional circumstances, the Commissioner may waive or reduce the non-Federal cost-share requirement if an overwhelming Federal interest and a significant financial need are identified. An example of an overwhelming Federal interest could include the need to address critical Endangered Species concerns.

Non-Federal cost-share contributions can include in-kind contributions to the specific study efforts, financial contributions toward contracted work, and funding to supplement Federal funds used by Reclamation staff to complete study tasks. The specific terms governing the non-Federal cost-share contribution and defining the cost-sharing approach for the study will be agreed to by the Cost-Share Partners and set forth in the MOA. If non-Federal contributions are used to support work by Reclamation staff or contractors, the Cost-Share Partners will also enter into a Contributive Funds Agreement. A Contributive Funds Agreement is the legal mechanism that is needed for Reclamation to receive non-Federal funding.

Because this is not a financial assistance program, Reclamation's share of the study costs may only be used to support work done by Reclamation or its contractors. Reclamation may not pass funding directly through to the non-Federal Cost-Share partners in the form of grants or other financial assistance.

4.4.3 Geographic Scope

The Basin Studies will focus on basins or sub-basins in the West where imbalances in water supply and demand exist or may exist in the future. The specific boundaries of the basin to be studied will be identified by Reclamation with the Cost-Share Partners through the proposal selection process described in 4.2 above. Once a study proposal is accepted and the basin is identified, the specific geographic boundaries of the study will be described in the MOA (see Sec. 5.3.1), as agreed to by the Cost-Share Partners. In general, the study area for each Basin Study will be identified according to relevant river basin boundaries. A river basin can be defined as a topographically distinct body of land, aquifer, streams, and rivers that channel water to a single or primary waterway.

4.4.4 Time Frame

In general, the Basin Studies must be completed within two years of the date that the MOA is signed. However, under certain circumstances, the schedule may be extended or the study may be divided into phases, depending on the scope and complexity of the study, the availability of applicable data and models, and the availability of appropriations.

4.4.5 Study Requirements

The Basin Studies will be conducted in a manner consistent with this Framework and the MOA. Each Basin Study will include four elements:

1) Projections of water supply and demand, including an assessment of risks to the water supply relating to climate change as defined in §9503(b)(2) of the SWA:

    a) changes in snowpack;
    b) changes in the timing and quantity of runoff;
    c) changes in groundwater recharge and discharge; and
    d) any increase in the demand for water as a result of increasing temperatures or the rate of reservoir evaporation.

2) Analysis of how existing water and power infrastructure and operations will perform in the face of changing water realities, such as population growth and climate change, including an analysis of the extent to which changes in the water supply will impact Reclamation operations and facilities as defined in §9503(b)(3) of the SWA:

    a) the ability of Reclamation to deliver water;
    b) hydroelectric power generation facilities;
    c) recreation at Reclamation facilities;
    d) fish and wildlife habitat;
    e) applicable species listed as an endangered, threatened, or candidate species under the Endangered Species Act of 1973 (16 U.S.C. 1531 et seq.);
    f) water quality issues (including salinity levels);
    g) flow and water dependent ecological resiliency; and
    h) flood control management.

3) Development of options to improve operations and infrastructure to supply adequate water in the future.

4) A trade-off analysis of the options identified, findings and recommendations as appropriate. Such analysis simply examines all proposed alternatives in terms of their relative cost, environmental impact, risk, stakeholder response, or other attributes common to the alternatives. The analysis can be either quantitative or qualitative in measurement.

Projections of water demands may include demands for agricultural, municipal, environmental, and recreational water uses, or other uses. Projections of water supply and demand will consider all potential water sources, including both groundwater and surface water.

A completed Basin Study must be documented in the form of a report (the Basin Study Report), due within the time provided for the study. The Basin Study Report will describe the four required elements, listed above; including the assumptions, models, research process, and data used in the study, and will describe stakeholder involvement, and the results and conclusions of the study.

4.4.6 Level of Detail

The level of detail of each study will vary depending on the level of existing data, models and useful studies available. In general, the level of analysis will be similar to an appraisal study because it is anticipated that Basin Studies will generate subsequent feasibility studies, either individually authorized or as generally authorized by the SWA. The level of detail in a Basin Study will not rise to the level of a feasibility study.

5.0 How to Conduct a Basin Study

5.1 Roles of the Cost-Share Partners

Reclamation will act as a co-lead for the study together with the non-Federal Cost-Share Partners. The Cost-Share Partners will establish a management structure for the study and will select the study manager and appropriate staff and participants to conduct the study. Reclamation will contribute to the technical aspects of conducting the studies, including input to the hydrologic and climate change analyses. Reclamation's technical involvement will vary depending on the needs of the non-Federal Cost-Share Partners and the scope and complexity of the study. Likewise, the technical involvement of the Cost-Share Partners will also vary, depending on the technical resources that they can contribute to the study. As described below (see Sec. 5.3.2), a Plan of Study (POS) will be developed by the Cost-Share Partners at the beginning of the study process. The POS will describe in detail the various tasks included in the study, the responsibilities of each of the Cost-Share Partners, the budget plan and schedule for the study.

5.2 Involvement of Basin Stakeholders in the Study Process

The Cost-Share Partners will develop an organizational plan for working with and allowing input from interested parties who are present or active in the basin, but who are not Cost-Share Partners. The plan will be included in the POS. Interested entities could include environmental, agricultural, power, or recreation groups, other study specific stakeholder groups, and basin water users. Other interested stakeholders could include state water resources, natural resources and environmental agencies, and Federal agencies, such as the USGS, U.S. Army

Corps of Engineers, Fish and Wildlife Service, NOAA Fisheries, and the U.S. Environmental Protection Agency, among others.

Reclamation anticipates that some stakeholders may simply want an opportunity to review and comment on the Basin Study, while others may want to contribute to the study. The Cost-Share Partners may agree to form working groups to conduct different aspects of the studies with the involvement of any of the stakeholders described here. Throughout the study, the Cost-Share Partners will make information available to basin stakeholders and request their input. Stakeholder input will then be incorporated into the Basin Study as appropriate.

5.3 Study Steps

Once a study has been accepted for funding, the following are the steps for conducting a study under the Basin Study Program:

5.3.1 Step 1 — Memorandum of Agreement

Reclamation and the non-Federal Cost-Share Partners will enter into an MOA stating the agreed-upon terms for each individual study. The MOA is the agreement used to establish the terms of the relationship between Reclamation and the other Cost-Share Partners. The terms for the study will be consistent with this Framework and will include a description of the all aspects of the Basin Study: (1) scope and general description; (2) geographic area; (3) goals; (4) study phases; (5) cost-sharing; (6) time-frame; (7) general responsibilities of the parties; and, (8) approach to incorporating input from stakeholders. The MOA will include the Plan of Study as an attachment.

5.3.2 Step 2 — Plan of Study

The POS, to be developed jointly by the Cost-Share Partners, will describe the specific study tasks and how each task will be carried out, including the responsible party and the methodology. The POS will be more detailed than the MOA and will serve as a work plan for the Cost-Share Partners. The POS must be drafted and agreed to by the Cost-Share Partners before substantive work on the Basin Study begins, and may be updated as conditions warrant. The POS may include:

1. Introduction
    - Purpose of Study - outcomes expected by the Cost-Share Partners
    - Study Objectives - scope and focus of the study
    - Description of Study Area
    - Organization of the POS

2. Study Description
    - Project Background
    - Problems, Needs and Opportunities
    - Previous Work and Available Data and Models
    - Current Activities
    - Resource Availability
    - Potential Alternatives

3. Study Approach and Interested Parties

4. Study Management Requirements
    - Project Management Plan
        - Study management Structure
        - Decision Making Process
        - Roles and Responsibilities
        - Study Team Coordination
        - Administrative Record
        - Schedule and Cost Control
        - Quality Control Plan
        - Deliverables and Project Documentation Requirements
        - Review Process - how the study will be reviewed including reporting requirements
    - Project Communication Plan
    - Public Involvement Plan

5. Study Tasks
    - Task 1
    - Task 2
    - Etc.

6. Milestones, Study Schedule, and Costs

7. Study Products

8. References and Appendices (if any)

5.3.3 Step 3 — Conducting the Study

Refer to the four required study elements listed in Section 4.4.5.

5.3.4 Step 4 — Review and Finalization of the Study

The Regional Director(s)[1] will be responsible for approving the Basin Study Report and ensuring that it meets the requirements of the Basin Study Program.

[1] Multiple Regional Directors may be required to approve a Basin Study Report if the geographic boundaries of the study overlap more than one of Reclamation's regions.

5.4 Suggested Content of a Basin Study Report

This Section outlines the suggested content that we anticipate will be needed to meet the four required study elements listed in Section 4.4.5 (Sections 5.4.1 through 5.4.4 track the four required study elements). However, we recognize that some studies may emphasize certain elements above others, depending on the priorities and needs of the non-Federal Cost-Share Partners, the issues present in the basin, and the availability of existing data, models, and other applicable analyses pertaining to the study area. For each part of the study described below, the Cost-Share Partners will incorporate and rely on existing data and analyses to the extent possible and will conduct new analyses where appropriate.

5.4.1 Hydrologic Projections of Water Supply and Demand

The analysis of existing and future water supply conditions will include consideration of key hydrologic factors that influence water supply within the basin. For example, examining ground and surface water interactions and return flows, and evaluating the impacts of climate change on water supplies.

a. Analysis of Existing Supplies. The study will involve characterizing *existing* water supplies in the basin. To the extent possible, the Cost-Share Partners will rely on existing data and analysis to evaluate existing supplies. This evaluation could include, for example: (1) analysis of historical stream flow data from stream gauges; (2) inflow and accretion data from gage measurements or models; (3) the use of rainfall runoff models to compute runoff from precipitation, temperature, topography, etc.; and (4) review of inflow forecasting processes based on snowpack levels, soil moisture and other physical measurements.

b. Projections of Future Water Supplies. The study will include projections of *future* water supply conditions using a 40 to 60 year planning horizon. To make these projections, the Cost-Share Partners will work with experts in hydrologic modeling, water supply forecasting and climate change. The studies will use the best available modeling to develop scenarios for projected changes in water supply due to climate change. (Additional discussion of the climate change analysis is provided in Table 1 and Attachment A). In considering future water supply conditions, the study will also consider any new facilities planned to be constructed, inter-basin transfers and other relevant factors affecting future supplies in the basin at issue.

c. Analysis of Existing Water Demands. The study will involve characterizing *existing* water demands within the study area, and using existing population and water use data to the extent that it is available, including, for example: (1) records of diversions and groundwater pumping; (2) land use and crop information, including corresponding consumptive use information; and (3) physical data regarding canal losses, system efficiency, deep percolation, and return flows.

d. Projections of Future Water Demands. The study will include projections of *future* water demand conditions using the same 40 to 60 year planning horizon used for water supply projections. To forecast future water demands, the Cost-Share Partners will consider: Anticipated changes in water-use due to population growth, climate change, increased demands for hydropower and other energy development, the environment, bio-fuels, recreation, water quality, and other uses; anticipated changes in land-use due to changes in crop patterns (e.g., transitions from low water use crops to higher valued crops that may require more water); changes related to compact obligations, transfers of irrigation supplies to municipal and other uses; and other factors that may influence future water demands in the basin.

5.4.2 Analysis of How Existing Water and Power Infrastructure Will Perform in the Face of Changing Water Realities

The Basin Study will assess the capability of existing and proposed infrastructure and operations to meet future demands and water supply challenges. This analysis will include an assessment of the operational risk and reliability of the system currently and in the future.

a. Baseline System Reliability Analysis. The study will characterize how well existing demands are being satisfied with existing infrastructure and operations. This analysis will require the Cost-Share Partners to identify appropriate metrics to measure system reliability. For example, a study might characterize system reliability in terms of the likelihood that water rights will be curtailed due to shortages over a 30 year (or other) period. The system reliability analysis will require the use of a model capable of simulating river basin operations under existing water supply conditions. Existing models or analysis tools may need to be enhanced to include all relevant river basin characteristics.

b. Projections of Future System Reliability. The study would next analyze system conditions under future water supply and demand scenarios and assess how future system reliability changes relative to baseline reliability. Models used in the analysis described above may be adapted to reflect future water supplies and demands instead of existing conditions. To assess uncertainty regarding future conditions, sensitivity analyses could be used to provide the full range of potential future

conditions and reporting on the associated range of potential future operations. The specific approach to accomplish this may vary depending on the types of tools available in a particular river basin.

5.4.3 Development of Options to Meet Future Water Supply Needs

a. Non-Structural Changes: These could include, for example:

- Operational changes
- Legal and institutional changes
- Water conservation and efficiency
- Water marketing
- Drought contingency measures
- Inter-basin transfers using existing facilities
- Conjunctive surface and groundwater use

b. Structural Changes: These could include, for example:

- Upgrades, rehabilitation, or replacement of existing facilities
- Water recycling and reuse facilities
- Desalination (brackish or seawater) facilities
- Use of an inter-tie to connect two water distribution systems
- Any facilities needed to implement non-structural changes
- Development of new facilities, including conveyance and storage facilities

c. Evaluation of the Options Identified. The study will identify and prioritize the structural and non-structural options considered. This analysis will include an evaluation of the environmental, economic/financial, and social impacts of the options considered. The study will also identify potential institutional, legal and regulatory constraints affecting the options considered.

Table 1, attached, provides further discussion of some of the technical study areas that may be addressed in developing options to meet future needs, including: (1) climate change; (2) treatment technologies; (3) consideration of institutional and regulatory restrictions; (4) economic and financial analysis; (5) environmental considerations; (6) social and public perceptions; (7) hydropower; and (8) recreation.

5.4.4 Findings and Recommendations

Based on the assessments developed during the study, the Cost-Share Partners will work together to develop a trade-off analysis of potential solutions to improve water supply reliability in the future. The trade-off analysis will be used to formulate solutions and as a mechanism for incorporating stakeholder input. The analysis will also identify potential institutional, legal and regulatory constraints affecting the solutions considered.

Following the trade-off analysis, the Cost-Share Partners will prepare findings and conclusions and will make recommendations in the report as appropriate. This section of the report may also identify the next steps that could be taken to implement the recommendations identified. However, Reclamation is not responsible for implementing study recommendations, which in most cases would require additional funding and authorization.

Table 1: Technical Study Areas to be addressed in Basin Studies

Technical Study Area	Relevance and Potential Study Approach
1. Climate Change and Hydrologic/Operational	Assessments of existing water supplies, projections of future water supplies, and analyses of existing/future water demands will be completed based on available data. These assessments will build off of existing hydrologic models available for the basin and will incorporate operational issues as appropriate to reflect current and future water management scenarios. A key element of the Basin Studies will be to incorporate climate change information into the development of projected water supply and demand conditions. Where appropriate, study teams may also relate climate change information to assumed operating constraints (e.g., flood control requirements, environmental demands). Attachment A to this Framework provides more detailed information regarding terminology, data sources, methods, and analytical approaches to guide Basin Study teams on how to factor climate change information into assumptions about supplies, demands, and operating constraints.
2. Treatment Technologies/Engineering	As appropriate, Basin Studies will identify the potential to use advanced water treatment processes and other improved treatment technologies for consideration of new water supplies. Also considered will be current treatment and brine disposal technologies contemplated for new supply and water recovery concepts, limitations, and operational issues. Studies will provide an overview of commercially available technologies to facilitate proposed changes and areas where technology improvements are needed to make concepts more practical and cost-effective.
3. Institutional/Legal/Regulatory	The uncertainties associated with the prospect of climate change can provide justification for reviewing and modifying water management and related institutional protocols that are more flexible and responsive to changes in underlying water supply and demand conditions. Changes to water supplies – quantity and quality – have legal, regulatory, and contractual implications. The institutional, legal, and regulatory analysis will identify potential impacts to the basin of losing water supplies through climate change. It will also assess

Technical Study Area	Relevance and Potential Study Approach
	existing constraints and opportunities for adding new water through the use of advanced water treatment systems or water imports to a watershed. The economic characteristics of institutional/legal/regulatory impacts will also be evaluated in the economic/financial section (see no. 4, below). Essentially, the institutional, legal, and regulatory analysis will ask "what kind of agreement would have to be crafted in order to address future realities, and at what cost?" Third party impacts will be identified in this section including impacts on downstream users, local agencies, Indian tribes, habitat, etc.
4. Economic/Financial	Economic analyses will examine the costs and benefits of proposed alternatives given available data and within study budget and time frame. Cost-benefit analyses (CBA) will be used to estimate net social benefits using techniques appropriate for comparing alternative projects. Discount rates will be chosen that are appropriate for the expected lives of the alternatives with maximum of 50 years. Nonmarket values of environmental, recreational, or other quality of life values will be considered only to the degree that such analysis fits within the budgetary constraints of the study. Importantly, an economic analysis should also consider the immediate opportunity costs of proposed alternatives. Other possible economic analyses include regional economic analyses, income and employment impacts, the value of supply reliability and security, and even the value of self-reliance in cases where the project is in local agency control. Where relevant and appropriate, a financial analysis will look at the means and ability to pay for the project, including Federal, State, and local financing methods. While the economic analysis describes "why" a given alternative might make sense from various perspectives; the financial analysis will illustrate "how" the project could be paid for and implemented.
5. Environmental	Hydrologic/operational changes in a watershed have potential environmental consequences, and the Basin Studies will assess opportunities to avoid or lessen potential conflicts associated with the reduction in existing supplies or the development of expanded water supplies. Moreover, habitat needs that are met as a result of changing flow regimes in a watershed and potentially affecting voluntary water transfers and trades will be identified; studies will seek to provide a description of the habitat "value" in the economic/financial assessment. Appropriate information will be developed to assist basin interests in gaining an understanding of the environmental and recreation problems associated with each condition or option, including in-reservoir as well as in-stream uses, habitats, etc.

Technical Study Area	Relevance and Potential Study Approach
6. Social/Demographic and Public Perception	Communities adopt new realities at varying paces. The Basin Studies will consider factors such as community perceptions of existing water issues and views about potential solutions for addressing imbalances. Existence of outspoken publics, influential sponsors, educational levels, historical patterns of technology adoption, familiarity with new realities, and the prevalence of technology within a community all combine to create a level of "community readiness" to adopt new ideas such as future water supply alternatives. These factors also help form public perceptions. To the degree possible based on available information, these factors will be assessed by characterizing a community's demographics in combination with the other technical analyses to determine how realistic it is that new strategies and recommendations could effectively be put to use in a target area.
7. Power Generation	Projections of water supplies and demands will incorporate assessments of existing and future hydropower demands and related operational issues. The impacts of climate change on hydropower availability and demands will be evaluated based on the outcomes of climate change assessments as described in Attachment A to this Framework.
8. Recreational	Basin Studies will inventory and assess current recreational uses related to basin water resources and related features (river systems, reservoirs, parks, etc.). Future impacts to existing recreational resources, as well as potential recreational enhancements, will be considered and addressed in the Basin Studies.

Attachment A: Climate Change Considerations for the Basin Studies

Generally speaking, *climate* describes expected temperature, precipitation, and other weather conditions during a specified period of time. *Climate change* is any statistical change in expected weather conditions and is typically assessed over a span of multiple decades. The Basin Studies represent Reclamation's first programmatic effort to include climate change as part of its planning studies.

Five steps for conducting a climate assessment as part of a Basin Study are proposed below. These steps would occur prior to the operations analyses (see Suggested Content, Section 5.4). Each step is discussed further, below.

(1) *Evaluate* existing projections of climate change in the study area;

(2) *Determine* the appropriate climate projection models to be used in the study;

(3) *Model* the impacts of projected climate change on water supply (basin hydrology);

(4) *Model* the impacts of projected climate change on water demand (e.g., agricultural, municipal, etc.); and

(5) *Characterize* the impacts of projected climate change on other operating constraints that may be influenced by climate.

Evaluate Available Climate Projection Information

The purpose of this step is to gather available climate projection information and evaluate that information for climate aspects, particularly trends in temperature and precipitation that are relevant to the Basin Study. For example, if the focus is on *seasonal to annual water supply trends*, evaluation might focus on projected changes in monthly to annual mean temperature and precipitation. Alternatively, if the focus is on *drought or extreme events*, evaluation might focus on assessing precipitation drought episodes in the projections, or identifying extreme months or periods of temperature and precipitation.

A suggested data resource is the Downscaled Climate Projections (DCP)[2] archive. This archive offers a useful starting point for surveying many climate projections and the spread of future climate possibilities over the study region. A climate projection is typically characterized by simulated temperature and precipitation conditions over time. A climate projection requires using a chosen global climate model (GCM) to simulate temperature and precipitation *responses* to a scenario of greenhouse gas (GHG) development for the atmosphere and starts from an assumed initial condition of the global climate. The GHG scenario is important for determining the global average climate while the initial condition is important for determining regional temperature and precipitation conditions and sequences within the projection. As a result, climate projections can vary significantly depending on choice of climate model, GHG scenario, and assumed initial conditions for the climate system, which can have significant impacts on basin-level assessments.

There are greater than 100 available climate projections given the multitude of available GCMs (>20), GHG scenarios, and initial condition possibilities. The most recently developed collection of projections are described in the Intergovernmental Panel on Climate Change Fourth Assessment (2007) and referred to as the World Climate Research Programme's Coupled Model Intercomparison Project phase 3 multi-model dataset (or, CMIP3 data).

CMIP3 data taken directly from GCMs are not suitable for regional (Basin) assessments as they do not offer the spatial precision needed for basin-level studies. Consequently, it is necessary to "spatially downscale" the GCM output. A number of peer-reviewed techniques exist for doing so, one of which was used to "downscale" 112 CMIP3 projections and produce the DCP archive mentioned above[3].

Determine the Appropriate Climate Projection Models to be Used in the Study

As indicated in the preceding section, Basin Study teams have access to many climate projections. On the whole, these projections portray a wide range of temperature and precipitation change possibilities over time. Study teams need to decide on how this "spread" of potential future climate possibilities will be represented in their particular Basin Study (e.g., either analyze all or most of the projections to represent this spread, or analyze a small set of projections that encapsulates the spread), and ultimately develop associated sets of future water supplies/demands/constraints assumptions for operations modeling.

[2] "Statistically Downscaled WCRP CMIP3 Climate Projections" at http://gdo-dcp.ucllnl.org/downscaled_cmip3_projections/

[3] See <http://gdo-dcp.ucllnl.org/downscaled_cmip3_projections/#About>.

Literature offers several frameworks for how to proceed with this step (see Suggested Reading). This decision can influence approach decisions in subsequent steps. For Basin Studies, teams might discuss a preferred framework with study stakeholders. If there is a preference for portraying a future climate "snapshot," the Reclamation (2008) reference offers a rationale for choosing an encapsulating set of climate projections (e.g., low, medium, and high; wet, no change, dry; etc.), where selection is based on how they portray climate change possibilities that are relevant to the study's future period, climate metrics, and region of interest. The projection selection rationale in Reclamation (2008) also addresses the question of removing climate models from consideration, potential basis for doing so, and why ultimately no models were eliminated from consideration in that study. If study teams prefer to portray a future "developing" climate (and sequences of climate variability from the GCMs, which may differ from historical observations), the Christensen and Lettenmaier (2007) reference offers a potential outline of methods for relating a large collection of climate projections to associated natural runoff, surface water supply, and operations *projections*.

Model Water Supply Impacts

Climate change impacts on water supply occur when changing temperature and precipitation result in changes to watershed hydrology, runoff, and ultimately surface water supply and hydropower generation. Both Reclamation (2008) and Christensen and Lettenmaier (2007) include methods for simulating surface water hydrologic responses to climate change. The two studies feature methods common to both: (1) choose a well-calibrated surface water hydrologic model, and (2) generate weather sequences that are compatible with this model *and* consistent with the space and time structure of the climate projections selected from the DCP archive. Both studies used a similar approach for weather sequence generation, described in detail in Reclamation's 2008 *Central Valley Project and State Water Project Operations Criteria and Plan Biological Assessment*. The need to generate weather sequences stems from the fact that DCP data are monthly and regularly spaced on a grid at roughly 12km intervals. In contrast, a chosen hydrologic model may represent watershed hydrology in lumped subareas that are defined by topography rather than by a regularly spaced grid. Likewise, the model will likely have to compute time-evolving water balances in these subareas on a daily or sub-daily time-step, which would be shorter than the monthly time-step of DCP data. Basin Study teams might anticipate the use of geographic information system (GIS) analysis in the spatial reconciliation portion of this task.

Neither of the two methods assesses groundwater supply response to climate change which may be a significant issue for some Basin Studies (e.g., trends in groundwater stocks, or trends in interaction with surface water conditions as climate changes). Basin Study teams may wish to explore methods to account for

groundwater supply changes and also interactions between groundwater and surface waters.

5.1.4 Model Water Demand Impacts: Basin Study teams may feel inclined to consider climate change effects on several types of water demands affecting operations. Two categories that may be more readily analyzed are agricultural and municipal water demand.

Analysis of agricultural water demands involves both physical modeling and anticipating demand management responses under climate change (e.g., mix of crops and irrigation technologies defining "district-level" demand). Physical modeling might include crop-specific consumptive use which can analyze plant water use response to changes in future precipitation conditions (i.e., rain-fed water supply that partially satisfies crop water requirements) and future temperature conditions (i.e., atmospheric water demand driving plant evapo-transpiration).

Analysis of municipal water demands might be conducted within frameworks that involve historical analysis of water use variability and statistical modeling to reveal relative importance of potential influences (e.g., weather anomalies, price changes, time of the year). The American Water Works Association offers resources to guide these types of municipal water demand evaluations (e.g., Billings and Jones 1996).

Basin Study teams may also wish to consider how climate change might affect other water demand categories (e.g., environmental water needs, hydropower generation demand and timing, reservoir "storage" demands for recreational purposes, etc.), although methods for doing so may be less straightforward or confounded by institutional or legal influences.

Characterize impacts on operating constraints

As a final step before proceeding to operations modeling (Section 4.5, step 2), Basin Study teams may wish to consider how climate change might affect system operational constraints independent of water supply and demand assumptions. For example, sea level rise possibilities and how that might affect "cross-Delta conveyance" constraints were featured within the methods of Reclamation (2008). Other examples, perhaps more prevalent throughout Reclamation, might include future temperature increases and their influence on the effectiveness of environmental flow constraints on reservoir release operations or increased rainfall and its impacts to flood control constraints on reservoir storage operations. Basin Study teams may wish to complement the operations analyses with sensitivity studies involving the adjustment of climate-dependent operating constraints within reasoned limits of variation under climate change.

Suggested Reading

The following two references illustrate implementation of steps (1)-(3), above.

- (Example #1, where system is portrayed for multiple "snapshot" climates) Reclamation (2008), "Sensitivity of Future CVP/SWP Operations to Potential Climate Change and Associated Sea Level Rise," Appendix R in *CVP/SWP OCAP Biological Assessment,* <http://www.usbr.gov/mp/cvo/ocapBA_2008.html>.

- (Example #2, where system is portrayed for multiple "developing" climates) Christensen, N.S., and D.P. Lettenmaier (2007), "A multimodel ensemble approach to assessment of climate change impacts on the hydrology and water resources of the Colorado River Basin," Hydrol. Earth Syst. Sci., 11, 1417–1434, <http://www.hydrol-earth-syst-sci.net/11/1417/2007/hess-11-1417-2007.html>

These examples should be regarded as suggested methodologies for Basin Studies. They represent contemporary approaches that have been informed by preceding literature efforts exploring climate change implications for hydrology and water supplies. These examples are limited in that they do not address issues relating climate change implications to societal water demands, or issues relating climate change to groundwater conditions and interaction with surface water.